NASDA's View of Ground Control in Mission Operations

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This paper presents an overview of the present status and future plans of the National Space Development Agency of Japan's (NASDA's) ground segment and related space missions. The described ground segment consists of the tracking and data acquisition (T&DA) system and the Earth Observation Center (EOC) system. In addition to these systems, the current plan of the Engineering Support Center (ESC) for the Japanese Experiment Module (JEM) attached to Space Station Freedom is introduced. Then, NASDA's fundamental point of view on the future trend of operations and technologies in the coming new space era is discussed. Within the discussion, the increasing importance of international cooperation is also mentioned.

Introduction

The National Space Development Agency of Japan (NASDA), established in 1969, is one of the two major space organizations in Japan; the other is the Institute of Space and Astronautical Science (ISAS). NASDA is responsible for developing the space system for practical use — meteorological observations, communications, broadcasting, and observation of Earth's environment.

On the other hand, the objective of ISAS is to do research in space science using satellites and rockets. It has a long history (since 1964) and has achieved excellent results in space science. ISAS has its own tracking and data acquisition (T&DA) capabilities, but NASDA provides orbit-determination results for low-Earth-orbit satellites.

In accordance with NASDA's charter, initially the agency devoted all its efforts toward realizing geosynchronous missions for practical use and has placed many satellites into orbit since 1977. After several experimental mission successes, the Japanese people have received full service from geosynchronous missions.

The next challenge for NASDA was to develop the Earth observation satellite series, and MOS-1 and MOS-1b were successfully placed into Sun-synchronous orbits in 1987 and 1990, respectively. The Japanese Earth Resources Satellite (JERS-1), carrying synthetic-aperture radar (SAR), was successfully put into orbit in 1992. Those satellites' data have been available to foreign space agencies since the MOS-1 launch. In parallel with those missions, NASDA has launched five Engineering Test Satellites (ETSs) since 1975 in order to verify new space technologies.

The corresponding ground support system has also been gradually developed since the early 1970s. NASDA's present ground segments for space missions consist of a spacecraft T&DA system and an Earth Observation Center (EOC) system. The T&DA system consists of the Tracking and Control Center (TACC), established in 1975, which is the focal point of satellite control and related operations, and four Tracking and Control Stations (TACSs), including the station at Kiruna, Sweden.

The EOC was initially established in 1978 as a center of Earth observation in Japan to receive, process, and distribute Landsat data. Since then, its capability has been enhanced to cope with both Japanese and foreign Earth observation satellite evolution.

Another new aspect of development in the ground segment is the Engineering Support Center (ESC) system of the Japanese Experiment Module (JEM) to be attached to Space Station Freedom (SSF), in which Japan is participating with international partners — the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA), and Canada.

As typically presented in the JEM project, the principal objectives of NASDA's space development have been dramatically changing since the late 1980s. The objectives have become to develop space as a new frontier of human activity with international partners — the "Mission from Planet Earth" missions.

Other types of missions are to utilize the space environment to produce new materials, to make new experiments useful for human life, and to monitor Earth's environment and resources globally from satellites in orbit — "Mission to Planet Earth" projects. In order to support these new types of space projects, the present ground segment also has to be changed and its capability enhanced in accordance with space segment developments.

In the following sections, NASDA's present and future spacecraft missions, related systems of the ground segment, and required technical research and development are briefly introduced.

SPACE MISSIONS OVERVIEW

In this section, the present NASDA spacecraft launch schedule, in which some missions are still under investigation, and the typical missions which will have great impact on the ground segments are introduced (see Figure 1).

THE ETSs

The first ETS was launched in 1975; NASDA has placed five such satellites into orbit to verify new space technologies. The fifth satellite — ETS-V — is still operational (since 1987) and is scheduled for a tele-education experiment within Asian countries as an International Space Year (ISY) campaign. At present, NASDA has three satellite projects that have been funded. Each mission is introduced briefly in the following sections.

ETS-VI

This is NASDA's largest geosynchronous satellite so far and will be launched in mid-1994 by the H-II launch vehicle. It has two major goals — to verify basic technologies of bus equipment for large-scale satellites and to verify wide-range communication technology from space network to mobile communication, as follows:

- Fixed and mobile communication
- Intersatellite communication: K-band, S-band, and feeder link
- O-band communication
- Laser communication

From the ground segment point of view, ETS-VI brings two types of new technologies: the space network and the end-user-oriented Operations Control Center (OCC) capability. Figure 2 shows the ETS-VI.

COMETS

COMETS is scheduled for launch in 1997. The major missions are listed below, except for bus technologies.

- Intersatellite communication
- 22-GHz broadcasting
- Ka-band mobile communication

COMETS will enhance NASDA's Space Network from ETS-VI and the system is expected to support such satellites as the Advanced Earth Observation Satellite (ADEOS) and ETS-VII.

Calender Year	92	93	94	95	96	97	98	99	2000
Launch Vehicle • H-II • J-I			▲TF-1 ▲TF-2	▲TF-3	△TF-1				△HOPE: H-II Orbiting Plane
ETS Series, etc			▲ VEP ▲ ETS-VI		▲COMETS	▲ETS-VII	▲OICETS		△DRTSs
Earth Environment Monitor	▲JERS-1			▲GMS-5	▲ADEOS			△ADEOS-II	
JEM/SSF					▲JFD		▲JEM#1	▲JEM#2	
Other Missions			▲OREX (Re-entry Exp)	▲SFU/ISAS	△TBD (Re-entry Exp)	▲TRMM/NASA			

▲ Scheduled launch
△ Under study

Figure 1. NASDA's Spacecraft Launch Schedule.

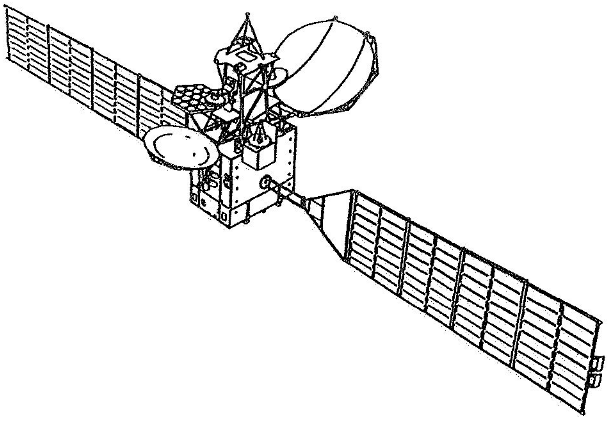

Figure 2. ETS-VI.

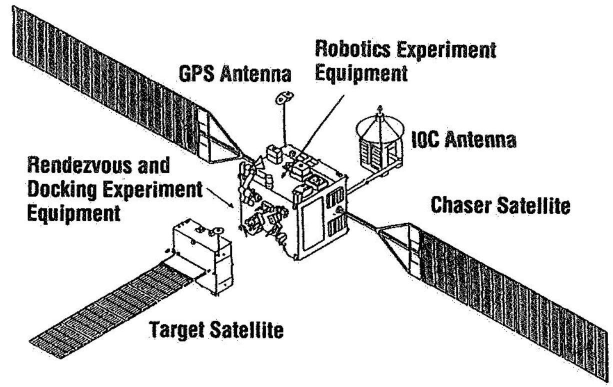

Figure 3. ETS-VII.

ETS-VII

The ETS-VII (see Figure 3) is the most challenging spacecraft ever planned by NASDA. It has two major missions: the unmanned Rendezvous and Docking Experiment and the Remote Controlled Space Robotics Experiment.

ETS-VII is composed of two satellites — Chaser and Target. The system is cooperatively controlled by the onboard computer and the ground system. The required technologies to be developed and verified through this mission will be a foundation for realizing a space transportation system in the early 21st century, except for the re-entry technology. The required ground segments also have many new challenging developments. For instance, NASDA needs to develop the technologies such as teleoperation, simultaneous two-satellite cooperative control, control via space network, and so on.

OTHER PLANS

The ETS-type satellites are very important for proving new technologies in space with low cost. So, NASDA is developing a new, relatively small launcher named J-1, which will be in service by 1996. As a first candidate small satellite, an experimental satellite for optical intersatellite communications is under study.

EARTH OBSERVATION PROJECTS

An Earth observation satellite has had a very important place in NASDA since the first launch of MOS-1 in 1987, by contributing to the observation of Earth's global environment and natural resources from space. The projects to follow JERS-1, launched this year, are introduced below.

ADEOS

ADEOS is a large-scale, composite-type satellite that will observe Earth's environment globally with several instruments. Two instruments — TOMS and NSCAT — are to be delivered by NASA, and POLDER will be delivered by the French space agency, Centre National d'Études Spatiales (CNES).

From an operations point of view, ADEOS will be the first Japanese satellite that can transfer data via the data-relay capability of COMETS. In order to efficiently operate payloads and to deliver observed data quickly to the end users, the OCC system has to have complicated scheduling functions and the EOC system needs to have the capability to quickly process and deliver a large quantity of data by the launch date.

FOLLOW-ON PROJECTS

The follow-on project to ADEOS, ADEOS-II, is under study and, after authorization by the Japanese government, the announcement of opportunity will be published to investigators both inside and outside of Japan. Like its predecessor, ADEOS-II will also be an international cooperative mission and will carry foreign users' equipment.

By the early 21st century, NASDA's Earth observing satellites will form a system with other agencies' satellites to supplement each other's capabilities through international cooperation.

SPACE STATION

In the SSF project, Japan will provide the JEM, which will be attached to the Space Station. The JEM consists of four major parts — pressurized module, experiment logistic module, exposed facilities, and manipulator (see Figure 4). JEM is scheduled to be put into orbit by NASA's Space Shuttle around 1998. In order to support JEM and the Japanese payload operations through experiments, and in case of anomaly, NASDA plans to develop an ESC in Japan.

Ground Segment

Based on the requirements from the present and future missions described above, NASDA's ground segment is continuously evolving and being enhanced. The status and future plans of NASDA's ground segment and related development and studies are introduced below.

T&DA System

The T&DA system consists of a TACC and four TACSs; one of the TACSs is at Esrange, part of the Swedish Space Corporation. The TACC is the focal point of NASDA's satellite control and has the principal roles, namely, operations control of satellites, T&DA network control, and supporting computation, including flight dynamics. Major satellites in operation are the Earth observation missions (MOS-1/1b and JERS-1) and ETS-V. The OCC of Earth observation at TACC keeps in close contact with the EOC in order to achieve full capabilities according to the requirements from mission users. An overview of related systems and plans are discussed in the following sections.

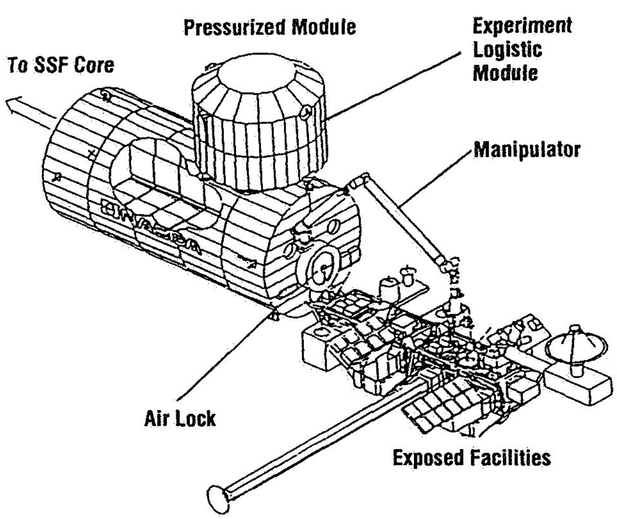

Figure 4. JEM.

Ground Network

The ground network consists of four TACSs; each TACS has two sets of unified S-band equipment. The network has been continuously upgraded since 1989, and a new capability to control TACS major equipment remotely from TACC is being developed. Most of the system has already been completed and the JERS-1 has been operated by the system. Implementation will be completed by the end of next April, and almost every TACS operation can be remotely performed from the TACC. This network can be connected with a foreign agency's network which is compatible with NASCOM via a gateway system. NASDA's ground network will continue to exist in the 21st century as the complementary part of the space network.

Space Network

NASDA's space network will play a very important role in future space operations. The first space network experiment is to be started in 1994 by using ETS-VI capability. The ground portion of the experimental space network system is under development at TACC in parallel with the satellite development. As the outline of the experiment in Figure 5 shows, NASDA also plans to verify interoperability of the space network with NASA's Tracking and Data Relay Satellite System (TDRSS). Then the COMETS experiment will follow in 1997. As a semi-operational system, the system will support several NASDA missions in the late 1990s.

By the early 21st century, NASDA will have a fully operational space network by launching two Data Relay and Tracking Satellites (DRTSs), which will have Ka-band and S-band intersatellite communication capabilities. In order to realize an interoperable space network in the near future, NASDA works closely with both NASA and ESA and has been participating in the Space Network Interoperability Panel (SNIP) with them. SNIP coordinates radio frequencies, modulation parameters, architecture of operation, etc.

In the coming 21st century, the NASDA system will take an important place in the global space network system in support of international space missions.

OCC System

NASDA's OCC system has been dramatically changing from the level of ETS-VI OCC system development. The OCC will have the capability to relay permitted commands and telemetry from/to several specified users' operations centers

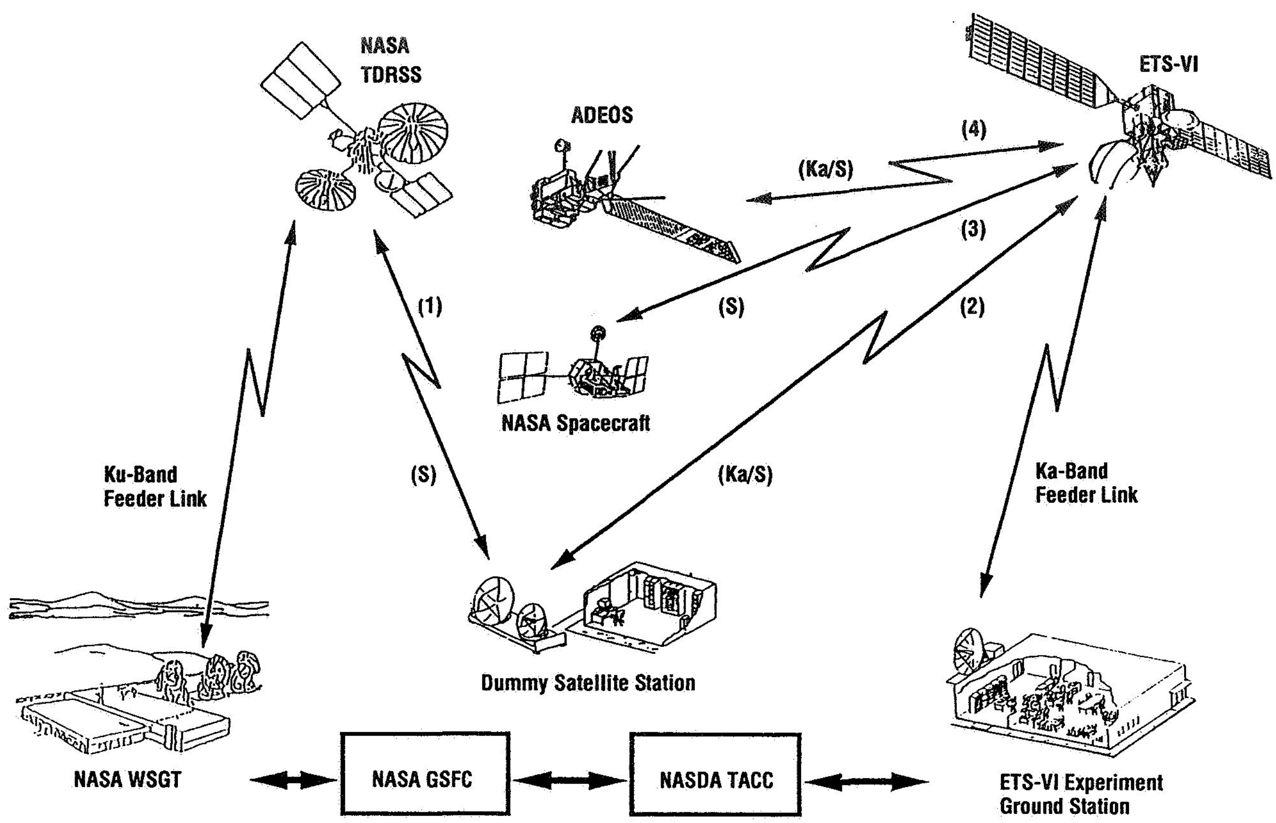

Figure 5. Space Network Experiment.

located in a remote area via the communication line. This will be the first step for NASDA to implement an end-user-oriented system. This capability will be further extended for the ETS-VII OCC system, which has to support unmanned rendezvous and docking activities and robotics experiments.

With missions becoming more complicated and capabilities of satellites growing, onboard computers will be employed to directly control some portion of the payload. This is the case of ETS-VII, and ADEOS will also carry many central processing units (CPUs) on board. This trend will bring some changes in OCC capabilities and may reduce some portion of the OCC load. However, OCC will need to cope with the complexity of future satellites. Its capabilities must be further enhanced to make detailed mission schedules in order to bring out the full capability of satellites safely, to assist ground controllers by providing some kind of satellite simulators in case of emergency, onboard software rewriting, and so on.

Technologies to be obtained through the development of ETS-VI, ETS-VII, and ADEOS ground control systems will be the foundation of OCC technologies for more advanced 21st century spacecraft.

FLIGHT DYNAMICS SYSTEM

The flight dynamics system supports flight projects and network operations by orbit and attitude determination and control. The present concern is to develop a new system to support the space network experiment carried out by using ETS-VI and to prepare for future Moon or planetary missions.

EOC SYSTEM

The EOC has two Earth observation systems that are capable of receiving and delivering data and will have another new system by ADEOS launch in order to enhance the capability to cope with ADEOS and future missions. As a next step, a direct data-receiving capability from the Japanese DRTS will be implemented by the time of the ADEOS-II launch in the late 1990s. At present, EOC receives data from the Earth observation satellites MOS-1/1b, JERS-1, Landsat, SPOT, and EERS-1.

NASDA is also promoting EOC as one of the Earth observation data centers of the world as a part of the activities of the Committee of Earth Observation Satellites (CEOS). The CEOS–International Directory Network (CEOS–IDN) has already been implemented and is connected to users both inside and outside of Japan and to systems belonging to foreign agencies such as NASA and ESA.

As introduced here, the EOC is becoming one of the Earth environment monitoring and data centers of the world. Present EOC capabilities are described briefly below.

MISSION CONTROL

Mission Control manages the payload operation plan based upon user request, keeping close contact with TACC. In the case of a foreign satellite, EOC summarizes Japanese users' requests and sends them to the satellite control centers.

DATA RECEIVING AND RECORDING

Data from each satellite are received by one of two antennas and recorded on high-density digital tape (HDDT) based upon the operation plan managed by Mission Control.

DATA PROCESSING AND EVALUATION

After data distortion correction by computer, data are recorded on computer-compatible tape (CCT). Image data are produced by printing on films using laser optics equipment, etc.

DATA ARCHIVING AND DELIVERING

The recorded HDDT, CCT, originally printed films, and catalogue of this information are archived and delivered according to the user's request. This capability will be greatly enhanced according to the above mentioned development of a new data center.

JEM ESC SYSTEM

NASDA plans to build the JEM ESC at the Tsukuba Space Center, which will be the first control center in Japan for manned flight and will support experiments performed at the JEM attached to the Space Station. The system will be connected to both SSOC and POIC in the United States via the international communication line. The capabilities of the ESC are to make an initial operations plan, to assist Japanese staff in coordinating experiment plans among the partners, and to monitor and evaluate JEM functions.

Before fully implementing the ESC system, NASDA is going to verify its capability by taking advantage of the JEM Flight Demonstration (JFD), which is scheduled to verify the JEM manipulator by using NASA's Space Shuttle in 1996. The details of ESC's capability are now under study, which is being done in coordination with international partners.

OTHER CONSIDERATIONS

NASDA's ground segment will be developed gradually in order to cope with future advanced missions planning to have interoperability among space agencies. Several key points common to the realization of such a ground segment for future missions are summarized below:

- Establishment of a space communications standard.
- Establishment of an interoperable space tracking and data network.
- Establishment of a global data network that is fully open to the user community and that enables users to utilize space data and to access the payload itself safely.
- Development of a secure and manageable operations control system for both autonomous and complex spacecraft.

CONCLUSIONS

As human activity in space moves from near Earth to the Moon or Mars and as Earth's environment becomes more important to the human race in the early 21st century, more space projects will be performed through international cooperation and require cost effectiveness. As the ground segment is developed accordingly, NASDA will continue to develop related ground systems and technologies, keeping close relations with its international partners.